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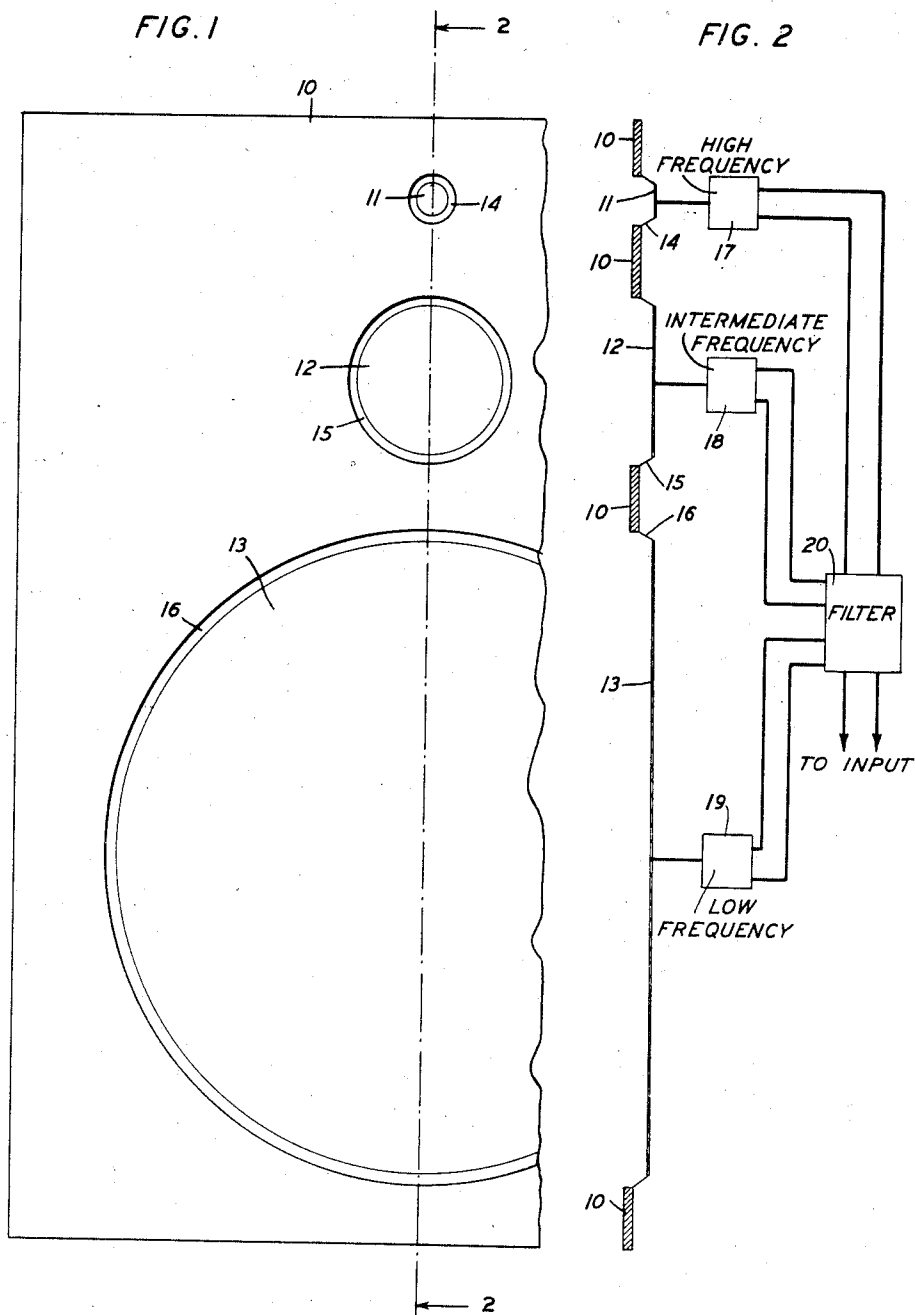
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1,965,405

ACOUSTIC DEVICE

Filed Feb. 28, 1933

3 Sheets-Sheet 1



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FIG. 3

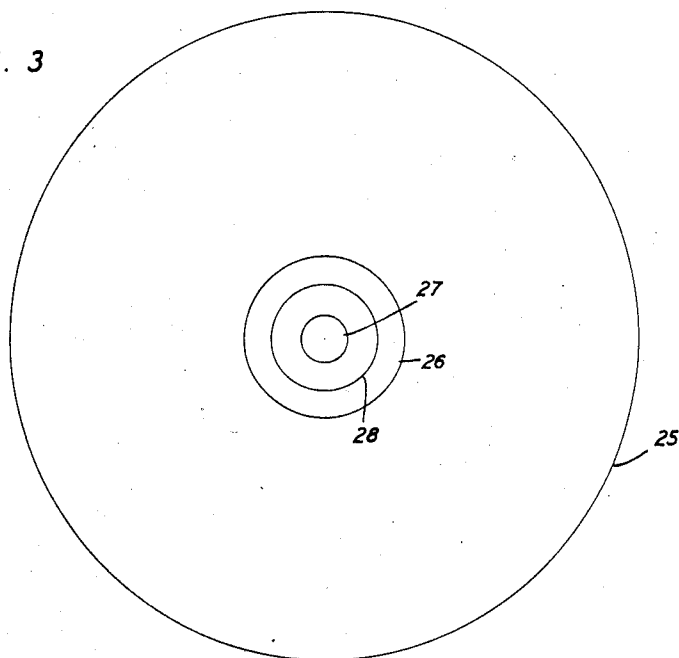
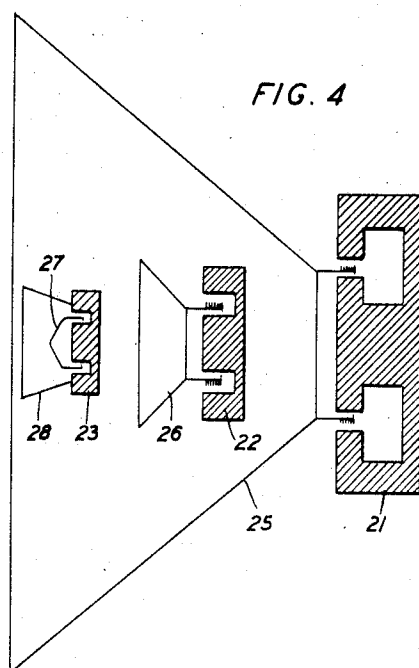


FIG. 4



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FIG. 5

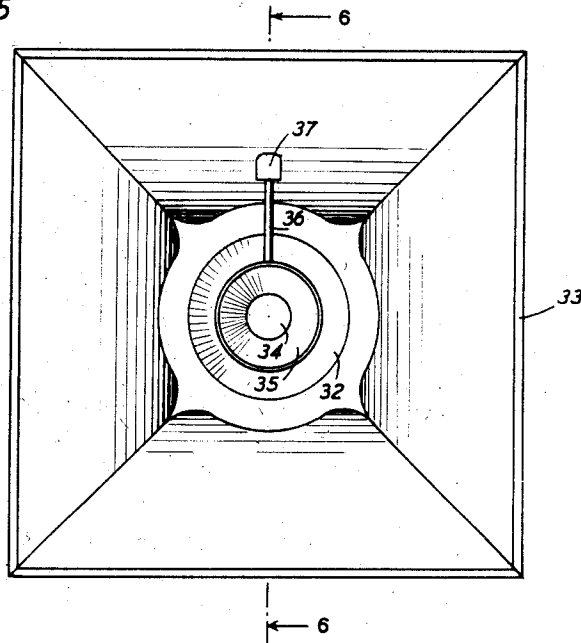
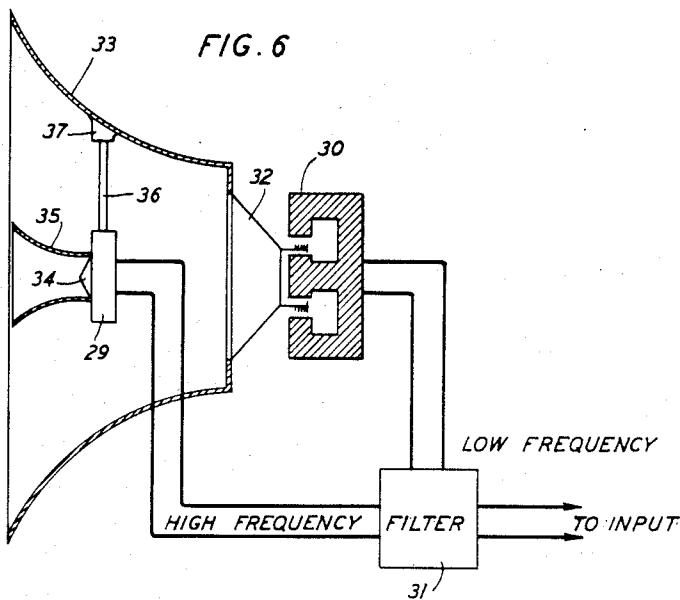


FIG. 6



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ACOUSTIC DEVICE

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9 Claims. (Cl. 181—31)

This invention relates to acoustic devices and more particularly to high quality sound reproducing apparatus including a plurality of loud speakers each of which is adapted to reproduce a limited band of frequencies in the audio-frequency range most efficiently.

One object of this invention is to reproduce speech and music efficiently and faithfully and with uniform distribution over a large solid angle.

In sound reproducing devices, it is known that the solid angle over which uniform sound distribution can be obtained is dependent upon the dimensions of the sound radiating element and upon the range of frequencies reproduced thereby. At the lower frequencies, the wave front of a sound radiating element is substantially hemispherical. At higher frequencies the wave front becomes very nearly planar. Hence, for a radiator of a given diameter the angle of distribution decreases as the frequency increases. For a given frequency the angle of distribution increases as the diameter of the sound radiating element is decreased. Although, therefore, good distribution can be obtained with a reproducing device, such as a loud speaker, in which the dimensions of the radiating element, such as a diaphragm, are small in comparison with the wave length of the sound propagated, it has been found that such a relation is not favorable from a standpoint of efficiency and uniformity of response.

In accordance with this invention, a plurality of sound reproducing devices are utilized, each of which is adapted to reproduce a limited band of frequencies most efficiently, the upper and lower frequency limits of the bands being so selected and correlated that a uniform performance is obtained throughout the entire range of frequencies of speech and music it is desired to reproduce. The sound radiating elements of the several reproducing devices are so constructed and proportioned that these elements are substantially uniformly non-directive at corresponding frequencies in the bands reproduced thereby.

The invention will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is a diagrammatic front view of a sound reproducing apparatus illustrative of one embodiment of this invention;

Fig. 2 is a view along line 2—2 of Fig. 1 and showing schematically an electrical filter associated with the several reproducers;

Fig. 3 is a diagrammatic front view of another

embodiment of this invention in which the several reproducers are coaxially disposed;

Fig. 4 is a side view of the apparatus shown in Fig. 3;

Fig. 5 is a front view of another embodiment of this invention in which one reproducer is mounted within a short horn or baffle to which the sound radiator of another reproducer is acoustically coupled; and

Fig. 6 is a cross-sectional view along line 6—6 of Fig. 5, and showing schematically an electrical filter associated with the several reproducers.

The sound reproducing apparatus shown in Figs. 1 and 2 comprises a panel or baffle 10 having a plurality of apertures therein. A plurality of sound radiators 11, 12 and 13 are associated each with corresponding apertures in the panel or baffle 10 and may be connected to the panel by flexible annuli 14, 15 and 16 which form acoustic seals between the radiators and the panel to prevent interference between the sound waves propagated by opposite surfaces of the radiators. Each of the radiators is connected to a corresponding one of the actuating units 17, 18 and 19 which may be of the armature, moving coil, or other suitable type. The radiators and actuating units are preferably designed to be equally efficient over different bands of frequencies within the audio-frequency range. For example, the radiator 11 and actuating unit 17 may be designed to reproduce the high frequencies most efficiently; the radiator 12 and actuating unit 18 to reproduce the intermediate frequencies most efficiently; and the radiator 13 and the actuating unit 19 to reproduce the lower frequencies most efficiently. The actuating units 17, 18 and 19 may be suitably connected each to a corresponding channel of a multi-channel electrical filter 20, which in turn is connected to a suitable source such as an amplifier.

In order to obtain a uniform sound distribution from the several reproducers, it has been found that a definite relationship should exist between the dimensions of the sound radiators 11, 12 and 13. For a circular sound radiator, the solid angle over which substantially uniform sound distribution can be obtained may be ascertained from the equation:

$$\theta = 4\pi \frac{.61N^2}{D^2f^2} \quad (1)$$

where

θ is the solid angle of distribution,

D the diameter of the sound radiator,

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f is the highest frequency in cycles per second to be propagated by the radiator,

N is the velocity of propagation of sound.

For radiators of other than circular form, Equation (1) may be used to compute the angle θ by determining the diameter of a circle having an area equal to that of the radiator in question and using the value of this equivalent diameter for D in the equation.

From Equation (1), it will be seen that the same angle of distribution can be obtained for a plurality of different radiators, if the product Df of the diameter of any radiator and the highest frequency to be propagated by that radiator is a constant for all of the radiators. That is, algebraically expressed:

$$D_1 f_1 = D_2 f_2 = D_x f_x = K \quad (2)$$

In a specific embodiment, for example, the highest frequency to be reproduced by the radiator 11 may be 15,600 cycles and the desired solid angle of distribution may be .66. From Equation (1) it follows, therefore, that the diameter of the radiator 11 should be about 2.3". The highest frequency to be propagated by the radiator 12 may be 3,000 cycles, and the diameter of the radiator should be, therefore, in accordance with Equation (2)

$$D = 2.3 \times \frac{15600}{3000}$$

or approximately 12". Similarly, if the highest frequency to be propagated by the radiator 13 were to be 575 cycles, the diameter of this radiator should be

$$D = 2.3 \times \frac{15600}{575} \text{ or } 62.5''.$$

In apparatus such as shown in Figs. 1 and 2, in which the diameters of the radiators are considered above, the filter 20 should be designed with three channels, one to pass the band from 3,000 to 15,600 cycles and connected to the actuating unit 17, one to pass the band from 575 to 3,000 cycles, and connected to the actuating unit 18, and another to pass the band up to 575 cycles and connected to the actuating unit 19. It is to be understood, that so far as this invention is concerned, it is not necessary to provide a filter to divide the energy between the different driving elements but is described here to show how to proceed in order to obtain maximum efficiency of the different reproducing devices within their respective frequency bands.

Although in the specific embodiment illustrated in Figs. 1 and 2, three radiators are employed, it will, of course be understood that a greater or lesser number could be employed within the scope of this invention. For example, a fourth radiator could be utilized, and adapted to reproduce most efficiently between say 21 and 110 cycles. The diameter of this radiator would be about 325". In this case the radiator having a diameter of 62.5" would be effective between 110 and 575 cycles.

It is to be understood, furthermore, that the frequency values and the angle of distribution chosen above are merely illustrative of this invention. Obviously, a large variety of other values could be used depending upon such factors as the range of frequencies to be reproduced, the space requirements, the characteristics of the individual radiators and actuating units to be employed, and others. Likewise, although the radiators of the apparatus shown in Figs. 1 and 2

have been described as flat and circular, it will be understood that they may be of other geometrical form such as polygonal or elliptical, and may be conical or otherwise dished.

It will be understood also that the radiators may be proportioned, if desired, that they have the same angle of distribution at other than the respective highest frequencies propagated thereby. For example, the radiators may be so proportioned that they are uniformly non-directional at the mean frequencies of the bands propagated or so that the product of the diameter, or equivalent diameter, of any radiator and a frequency within the band translated thereby is equal to the product of the diameter, or equivalent diameter, of any other radiator and a corresponding frequency in the band translated by each other radiator, the several frequencies being the same per cent of the maximum frequency translated by the respective radiators. The greater the percentage is, the greater will be the range of frequencies propagated through the angle desired.

Figs. 3 and 4 show another embodiment of this invention, employing a plurality of moving coil actuated loud speakers 21, 22 and 23. The diaphragms 25 and 26 in the loud speakers 21 and 22, respectively, are frusto-conical and axially aligned, the loud speaker 22 being disposed within the diaphragm 25 of the loud speaker 21. The loud speaker 23, which may also be disposed within the diaphragm 25 comprises a dished or conical diaphragm 27 which is axially aligned with the diaphragms 25 and 26, and a small horn 28, which may be exponentially flared, and designed to pass the particular band of frequencies to be radiated by the diaphragm 27 most efficiently. The loud speakers may be designed to reproduce individual bands of frequencies most efficiently and may be associated with corresponding channels of an electrical filter in the same manner as shown in Fig. 2. Diaphragms 25, 26 and 27 are proportioned in accordance with Equations (1) and (2) as pointed out in greater detail in the description of the embodiment of this invention shown in Figs. 1 and 2.

Although three diaphragms of general conical form are shown in Figs. 3 and 4, it will be understood that a greater or lesser number of diaphragms could be used and that the diaphragms might be of other forms without departing from the scope of this invention.

Another embodiment of this invention shown in Figs. 5 and 6 includes a high frequency loud speaker 29 adapted to reproduce the higher frequencies of speech and music most efficiently and a low frequency loud speaker 30 which is designed to be most efficient throughout the lower portion of the audio-frequency spectrum. The loud speakers 29 and 30 are connected with corresponding channels of a filter 31. The low frequency loud speaker 30 comprises a large frusto-conical diaphragm 32 acoustically coupled to the throat of a short horn or baffle 33 which may be flared exponentially away from the diaphragm. The loud speaker 29 comprises a relatively small diaphragm 34, acoustically coupled to a small horn 35, which may also be of the exponentially flaring type. The loud speaker 29 may be supported from the short horn or baffle 33 by a strut 36 which is secured to a flange 37 on the horn or baffle 33. The diaphragms 32 and 34 may be axially aligned, although they need not be so, and are proportioned in accordance with Equations (1) and (2) so that the angle of distribu-

tion for both the loud speakers is the same at corresponding frequencies in the bands reproduced thereby.

What is claimed is:

5 1. An acoustic device comprising a plurality of sound radiators each adapted to translate a separate band of frequencies within the audio range, the product of the equivalent diameter of any radiator and a frequency within the band translated thereby being equal to the product of the equivalent diameter of any other radiator and a frequency in the band translated thereby, said frequencies being the same per cent of the maximum frequency translated by the radiators corresponding thereto.

10 2. An acoustic device comprising a plurality of sound radiators each adapted to translate a separate band of frequencies within the audio range, the product of the equivalent diameter of any radiator and the maximum frequency which said radiator is to reproduce being substantially equal to a similar product for each of the other radiators.

15 3. An acoustic device comprising a plurality of circular sound radiators each adapted to translate a separate band of frequencies within the audio range, the product of the diameter of one radiator and the maximum frequency said radiator is to translate being substantially equal to the product of the diameter of each of the other radiators and its corresponding maximum frequency.

20 4. An acoustic device comprising a plurality of diaphragms of different sizes each adapted to translate a separate band of frequencies within the audio range, said diaphragms being coaxially disposed and having the same angle of distribution at corresponding relatively high frequencies in the frequency bands translated thereby.

25 5. An acoustic device comprising a plurality of coaxial diaphragms of different sizes and adapted each to reproduce a particular band of frequencies of importance in speech and music, the product of the equivalent diameter of the diaphragm and the highest frequency to be reproduced thereby being substantially the same for all of said diaphragms.

30 6. An acoustic device comprising a plurality of loud speakers each including a diaphragm and actuating means for the diaphragm, each diaphragm being adapted to reproduce a par-

80 ticular band of frequencies in the audio range most efficiently, the highest frequency reproduced by one diaphragm being substantially equal to the lowest frequency reproduced by another diaphragm, said diaphragms having substantially the same angle of distribution at the highest frequencies reproduced thereby.

35 7. An acoustic device comprising a plurality of coaxial dished circular diaphragms of different sizes, each of said diaphragms being adapted to reproduce a particular band of frequencies within the audio-frequency range most efficiently, the highest frequency in the band reproduced by one diaphragm being substantially equal to the lowest frequency in the band reproduced by another of said diaphragms, the product of the diameter of the diaphragm and the highest frequency reproduced thereby being substantially the same for all of said diaphragms.

40 8. Sound reproducing apparatus comprising a flaring baffle, a diaphragm acoustically coupled to one end of said baffle, a loud speaker within said baffle including a horn directed in the same direction as said baffle, a diaphragm of smaller size than said first diaphragm acoustically coupled to said horn, said diaphragms being adapted to reproduce separate bands of frequencies of importance in speech and music, and having substantially the same angle of distribution at corresponding relatively high frequencies in the bands reproduced thereby.

45 9. Sound reproducing apparatus comprising a flaring baffle, a large diaphragm acoustically coupled to the smaller end of said baffle, means for actuating said diaphragm, a loud speaker within said baffle including a horn flaring in the same direction as said baffle, a relatively small diaphragm acoustically coupled to the throat of said horn, and actuating means for said small diaphragm, said large diaphragm and the actuating means therefor being adapted to reproduce only a band of frequencies in the lower portion of the audio range, said small diaphragm and the actuating means therefor being adapted to reproduce a band of high frequencies extending from the highest frequency reproduced by said large diaphragm, and said diaphragms having substantially the same angle of distribution at the highest frequency in the bands reproduced thereby.

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